Environmental Stewardship and Drugs as Pollutants

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It is early morning—do you know where your drugs are? More than likely, some are on their way to local streams, rivers, and perhaps even farms, as sewage biosolids used as fertiliser. The public's inseparable connection to the environment is illustrated by an emerging understanding of drugs as environmental pollutants. That any chemical introduced commercially has the potential to find its way into the environment is not surprising, but pharmaceuticals and personal-care products as environmental pollutants have captured the attention of the public and the mass media because such pollutants result not primarily from manufacturing but from widespread and continual use in human and veterinary clinical practice.

Beginning in the 1970s, an escalation of research and monitoring, mostly by analytical chemists, has revealed the propensity for drugs and metabolites to enter the environment — usually by treated and untreated sewage. Many drugs from a wide array of therapeutic classes have been established as ever-present trace environmental pollutants in surface and ground waters,[1–5] generally occurring at concentrations (eg, ng/L–µg/L) far below human therapeutic levels. Although drugs, by contrast with most conventional (regulated) pollutants, are usually nonvolatile, they can also end up on the land by the disposal of sewage biosolids. Also, and again by contrast with most regulated pollutants, which have longer environmental halflives, the continual environmental introduction of drugs by sewage effluent makes them "pseudopersistent" pollutants with ramifications for aquatic organisms. The precautionary principle, given the worldwide importance of freshwater resources, underscores the need to minimise any impacts on water supplies (eg, treatment of wastewater for reintroduction and storage in groundwater drinking supplies) and resultant potential for human or ecological cumulative exposure.

The many facets of this complex issue are captured in several reviews[1–5] and on the US Environmental Protection Agency's web site.[6] The most comprehensive environmental monitoring-project is being published in stages by the US Geological Survey.[7] For risk assessment, published work (almost exclusively in the non-medical literature) has focused predominantly on environmental origins and sources and on occurrence,[1–5,7] and more recently on treatment-processes for waste and drinking water. Much less is known, however, about human and ecological exposure, and less yet about the known or potential hazards associated with multiple exposure to these synthetic substances, many of which are highly bioactive (eg, 17α-ethinyloestradiol).[2,4]

Regardless of whether drugs and personal-care products as environmental pollutants eventually prove to pose ecological or human-health risks, there are three major but still largely unrecognised reasons—unrelated to the molecules themselves—for developing means of reducing their introduction to the environment. By taking various actions to reduce the purposeful (eg, disposal of unused drugs via toilets) and inadvertent (mostly by excretion) release of such compounds, significant collateral benefits could arise for people as well as for their environment.

First, any improvement in technology for the removal of trace levels of drugs from waste and drinking water will more than likely also remove other unregulated pollutants, many of which have yet to be identified and others of which will come from new commercial chemicals. Thomas Ternes and colleagues[8] recently demonstrated that simple treatments, such as ozone oxidation or activated-carbon adsorption, albeit techniques not widely used, can efficiently remove drugs from drinking water. However, oxidative treatments (ozonation as well as chlorination and ultraviolet irradiation) can create many daughter products from parent chemicals; true mineralisation can be difficult to achieve. Other oxidative processes, such as ultraviolet irradiation, or physical removal, such as membrane filtration, used simultaneously or sequentially, should remove drugs and other xenobiotics.

Second, any efforts at pollution prevention (source reduction, minimisation, elimination[2,6]), most of which would originate from a broad range of sectors in the healthcare industry, could have significant consequences for improved consumer-health and reduced health-care spending. Third, the risks (if any) posed by drugs as environmental pollutants must be considered only as part of the larger risk-puzzle. Organisms are rarely ever exposed to just one toxicant at a time. Their vulnerability (or tolerance) is a multidimensional function of many variables throughout the duration of exposure to anthropogenic and naturally occurring toxicants. Any adverse effect is a function of not just current exposure but also combined exposure history.

An organism's tolerance depends on the duration of exposure to many chemical (and non-chemical) stressors, many of which share the same mechanism of action and whose effects can therefore at least be additive. Indeed, recent work is beginning to better show the significance of exposure to mixtures of chemical stressors at low concentrations. Nissanka Rajapakse and colleagues[9] showed that a mixture of 11 xeno-oestrogens, where each was below its no-observed-effect level, significantly increased the action of 17β-oestradiol in the yeast oestrogen-screen. Reaching a rational assessment of the risks posed by drugs as environmental pollutants needs to be done with a minimum investment of resources, which means avoiding reinvention and rediscovery. The synthesis of reports that span many fields has a key role,[6] as does the critical need for collaboration between the traditionally separated environmental and medical sciences. Almost nothing has been published in the medical literature with the stated objective of determining the causes, extent, risks, or solutions to the issue of drugs as pollutants.[10] Collaborations among the environmental and medical sciences are important because in the final analysis, human health and the "health of ecology" are intimately tied, and in many respects, indistinguishable.

CGD's views do not necessarily reflect the views and policies of the US Environmental Protection Agency.

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